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6. AUTHOR(S)
RICHARD BARLOW

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ENGINEERING SYSTEMS RESEARCH CENTER
3115 ETCHEVERRY HALL
UNIVERSITY OF CALIFORNIA AT BERKELEY
BERKELEY,CA 94720-1777

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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To: Mr. Ed Hawkins
AFOSR/PK
110 Duncan Ave.
Suite B115
Bolling Air Force Base
Washington, D. C. 20332

cc. Dr. Jon Sjogren
AFOSR/NM
Bolling Air Force Base
Washington, D. C. 20332-6448

AFOSR # F49620-93-1-0011

P. I. Richard E. Barlow

Engineering Systems Research Center
3115 Etcheverry Hall
University of California at Berkeley
Berkeley, CA 94720-1777

FINAL REPORT

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SUMMARY

We have concentrated on problems in engineering reliability and have recently completed a draft of a book on this topic containing much of the research developed under the AFOSR grant. Two Ph.D. thesis students supported by this grant have now graduated. Their research will also be described.

Preface to ENGINEERING RELIABILITY

The book ENGINEERING RELIABILITY concerns failure data analysis, the economics of maintenance policies and system reliability. The purpose of this book is to develop the use of probability in engineering reliability and maintenance problems. We use probability models in the

1) analysis of failure data;

2) decision relative to planned maintenance;

3) prediction relative to preliminary design.

Engineering applications are emphasized and are used to motivate the methodology presented.

Part I of the book is devoted to the analysis of failure data, particularly lifetime data and failure counts. We begin by using a new approach to probability applications. The approach starts with finite populations and derives conditional probability models based on engineering and economic considerations. Infinite population conditional probability models most often used are approximations to these finite population models. The derived conditional probability models are then the basis for likelihood functions useful for the analysis of failure data.

Part II of the book is devoted to the economics of maintenance decisions. We begin with the economics of replacement decisions. Emphasis is on the time value of money and discounting. Then we consider inspection policies relative to operating systems and production sampling.

Part III of the book is devoted to system reliability. We begin with efficient algorithms for computing network reliability. Networks or "block diagrams" are abstract system representations useful for both reliability prediction and maintenance considerations. Availability and maintainability formulas are

derived and used in applications. Fault tree analysis as presented is one of the most useful tools in identifying system failure modes and effects.

Perhaps the most mathematically sophisticated work on this grant was the Ph.D. thesis of Pei-sung Tsai, *Probability Applications in Engineering*, completed in July 1994.

Abstract: A probabilistic approach is developed to utilize physical knowledge of stresses, and incomplete stress measurements, for assessing the magnitudes of principal stresses. Tri-axial stress uncertainty arises when the six stress components in a stress tensor are not all observed. The likelihood of the observed stress measurements is derived conditional on the principal stresses- the parameters. The likelihood model is "derived" (not conveniently assumed) based on the laws of stress transformation and the invariant probability measure. An engineer's "a priori" belief, regarding the domain and probability distribution of the principal stresses, can be used as a prior distribution. An a posteriori distribution is a revision of the belief after the stress measurements are observed, and is calculated using Bayes formula.

A Ph.D. thesis, *Bayesian Probability Modeling for Engineering Applications* and supported by this grant was completed in late 1995 by SunEung Ahn.

Abstract: The thesis is concerned with

i) stress analysis,

ii) fatigue life in the presence of crack propagation under a variable-amplitude load

and

iii) burr/breakout formation in a face milling manufacturing operation.

In the machining of automobile engines, undesirable burrs are created. (A burr is defined as plastically deformed material left and attached on the workpiece after machining.) The burrs produced on a piece part edge in machining operations must be removed for the part to function efficiently. Consequently, depending on the application, edge breakout would be more desirable than burrs because the deburring time could be significantly reduced.

Probability models for analyzing burr-formation data based on experiments with gray cast iron material obtained from General Motors Corporation have been developed. Unlike ductile material such as carbon steel or aluminum alloy, cast iron exhibits a random

burr/breakout edge profile during the face milling operation. The problem is to determine the effect of feed cutting speed and the RPM of the rotating cutting tool on the number of burrs created.

The probability of burr formation is defined and derived based on orthogonal cutting theory by considering the uncertainty in shear angle as the primary cause of edge-profile variability. Specifically, based on orthogonal cutting theory, the probability that a burr forms in a unit cutting path after a face milling operation is derived. Burr/breakout data is obtained from photographic edge profiles of machined work material and then used to update the probability model. Work on ways to present these results relative to the decision problem of selecting the best controllable variables is still in progress.

Also working with Professor Dornfeld and one of his Ph.D. students in Mechanical Engineering we have developed probability models for analyzing burr-formation data based on experiments with gray cast iron material obtained from General Motors Corp. Unlike ductile material such as carbon steel or aluminum alloy, cast iron exhibits a random burr/breakout edge profile during the face milling operation. The problem is to determine the effect of feed cutting speed and the RPM of the rotating cutting tool on the number of burrs created.

We define the probability of burr formation and derive it based on orthogonal cutting theory by considering the uncertainty in shear angle as the primary cause of edge-profile variability. Specifically, based on orthogonal cutting theory, we derive the probability that a burr forms in a unit cutting path after a face milling operation. Burr/breakout data is obtained from photographic edge profiles of machined work material and then used to update our probability model.

This work completes our AFOSR project effort.

Personnel supported:
Faculty:

Richard Barlow

Ph.D. thesis students:

Peisung Tsai (Ph.D. December 1994)

SunEung Ahn (Ph.D. May 1996)

Publications:

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